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(54) **FAILOVER AND FAILBACK OF COMMUNICATION BETWEEN A ROUTER AND A NETWORK SWITCH**

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Related U.S. Application Data

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(52) **U.S. Cl.**
USPC **370/225**

(58) **Field of Classification Search**
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See application file for complete search history.

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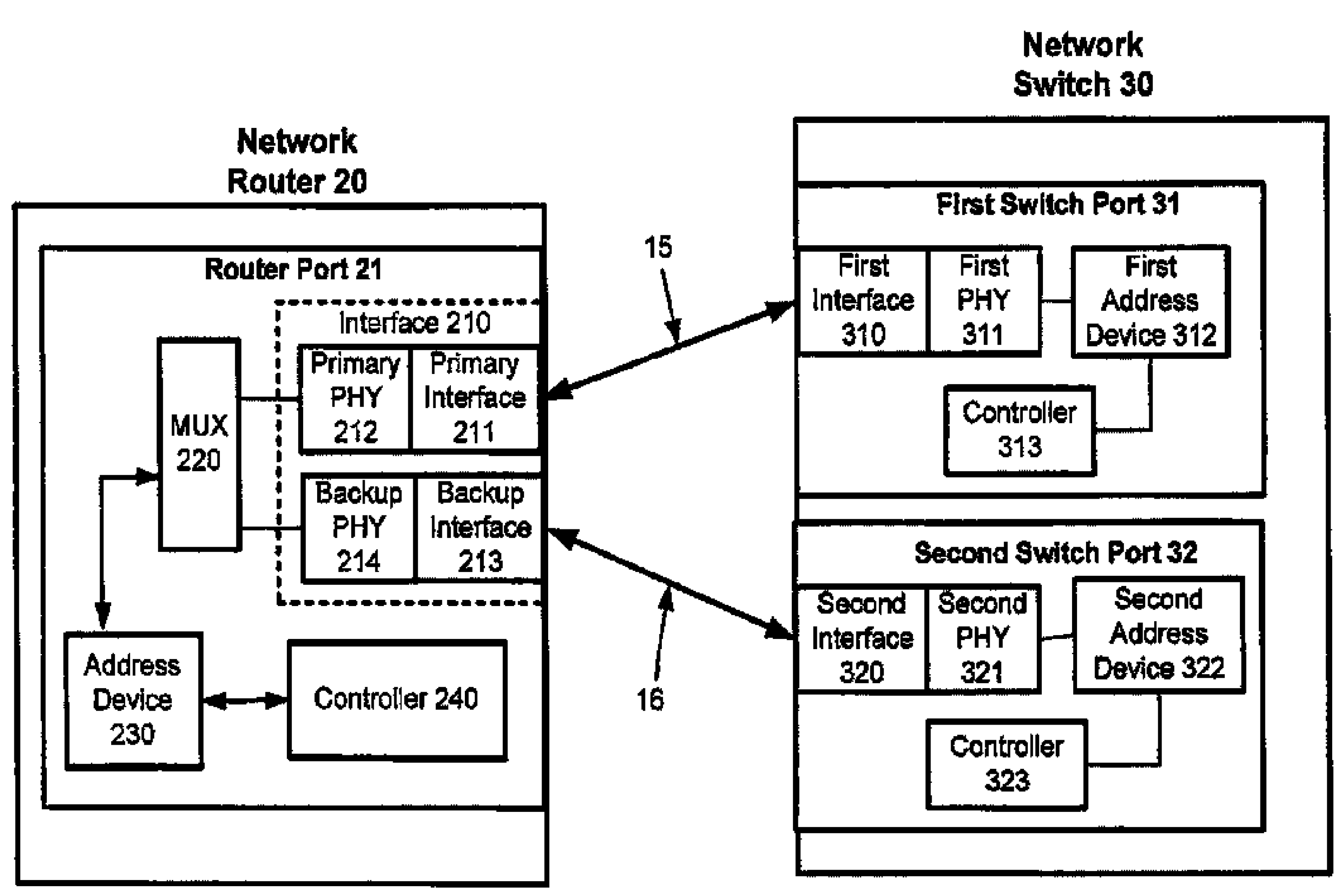
(57) **ABSTRACT**

A router is provided. The router includes a primary interface, a backup interface, a processor, and a memory. The primary interface and backup interface may be used to communicate with a network switch. The router may be configured to determine whether the primary interface is stable. The primary interface is stable when the primary interface may be used to exchange information with a network switch over a primary network segment. The router may be configured to activate the primary interface when the primary interface is determined to be stable. The router may also be configured to activate the backup interface when the primary interface is determined to be not stable. The backup interface may be activated for the exchange of information with the network switch.

20 Claims, 9 Drawing Sheets



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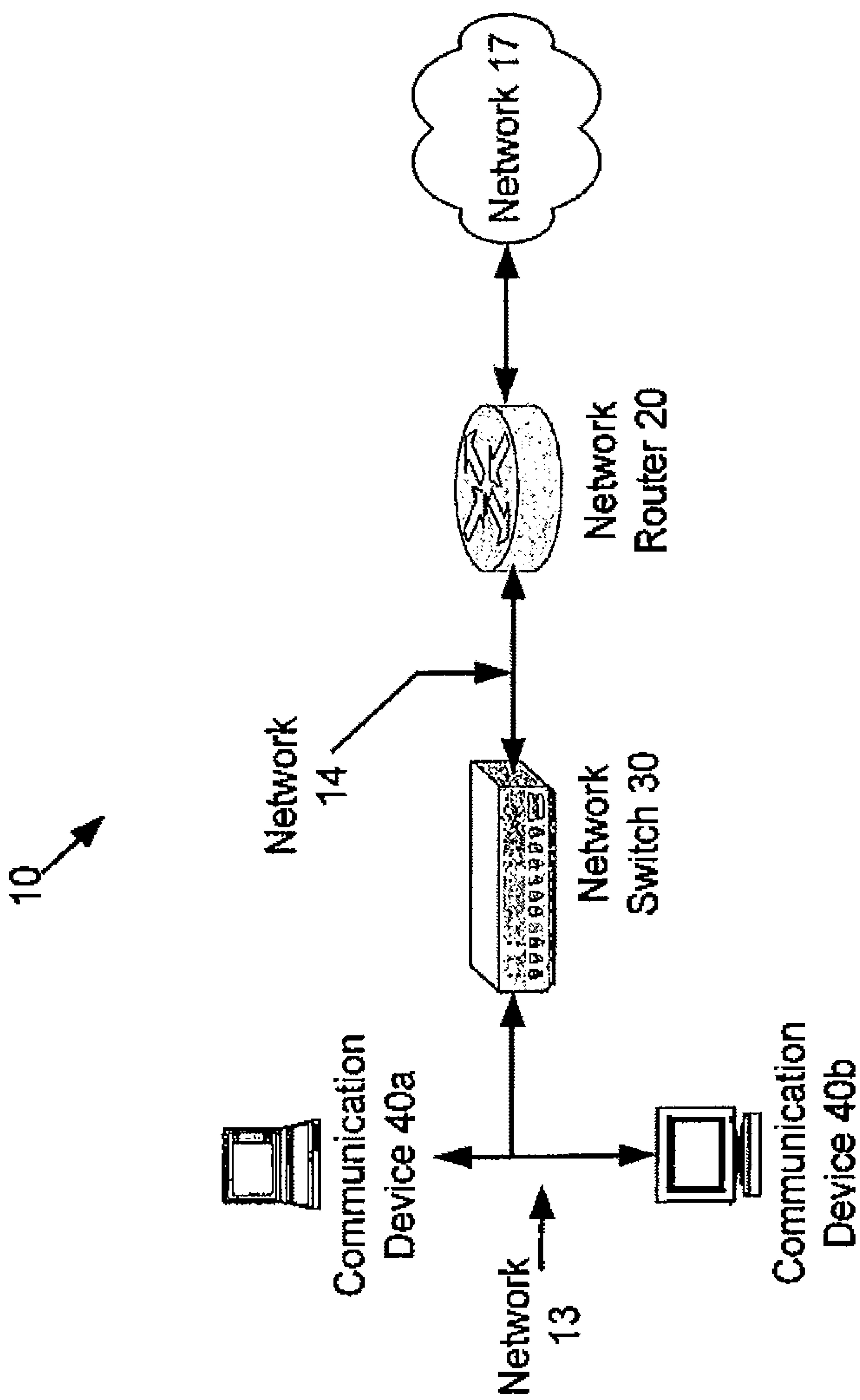
10
Network 17
Network Router 20
Network 14
Network Switch 30
Communication Device 40a
Network 13
Communication Device 40b

FIGURE 1

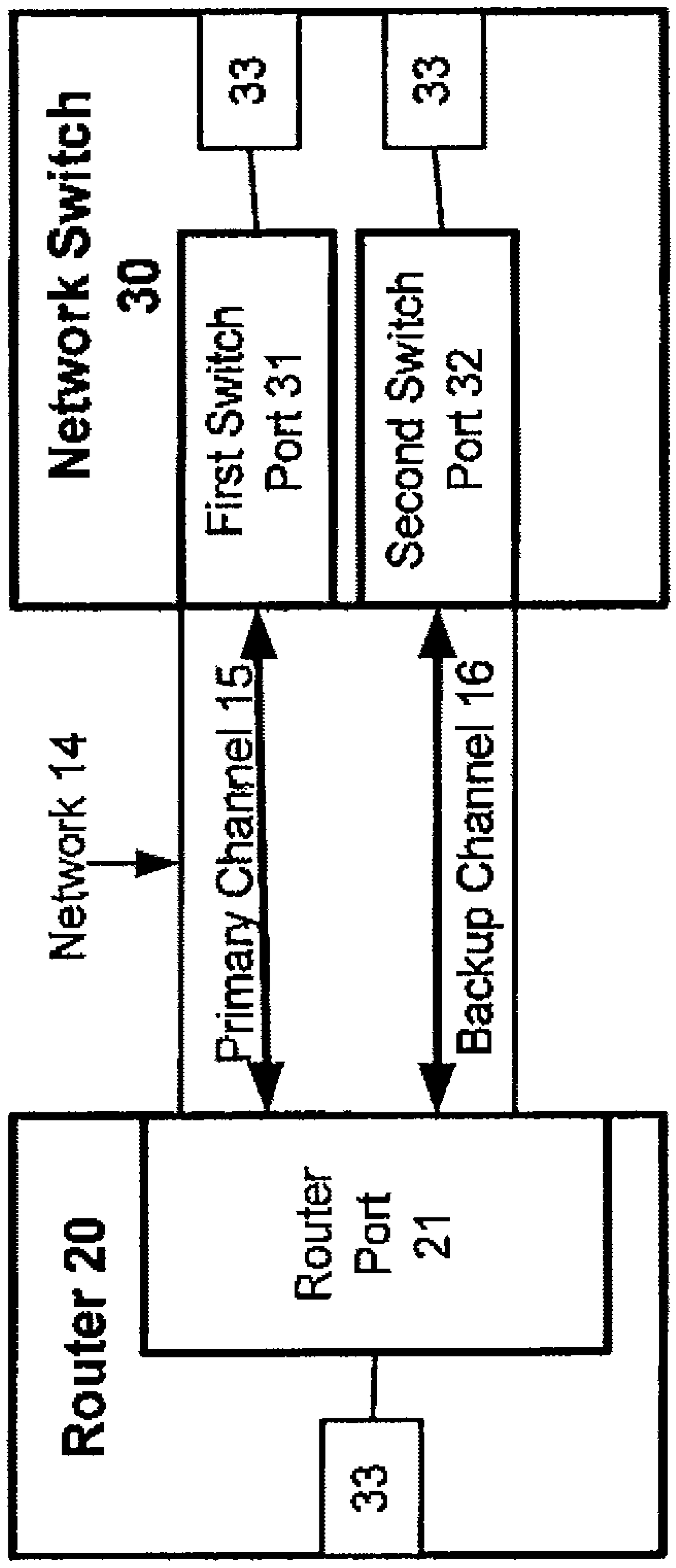
Network Switch 30
33
33
First Switch Port 31
Second Switch Port 32
Network 14
Primary Channel 15
Backup Channel 16
Router 20
Router Port 21
33

FIGURE 2

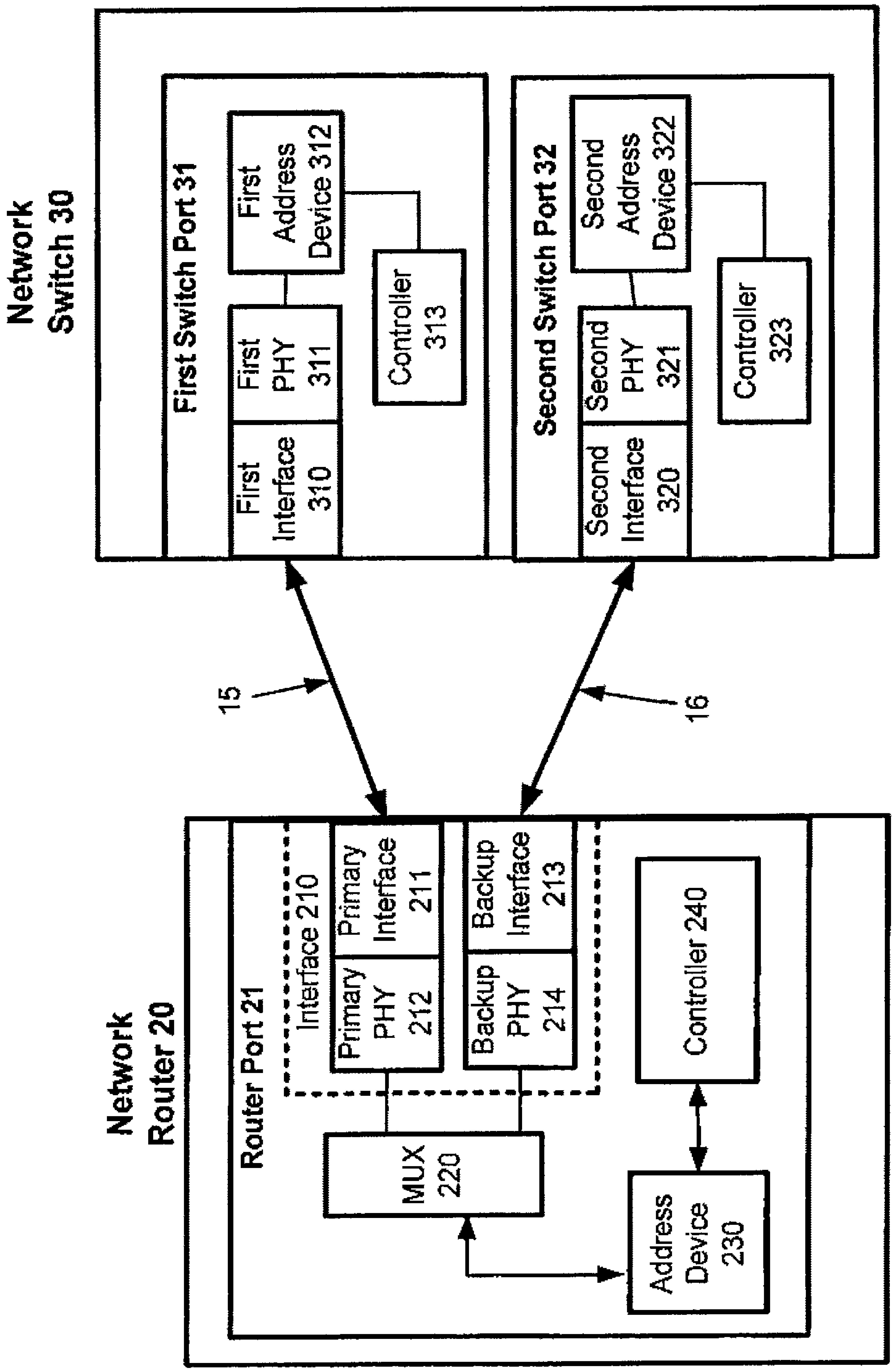
Network Switch 30
First Switch Port 31
First Interface 310
First PHY 311
First Address Device 312
Controller 313
Second Switch Port 32
Second Interface 320
Second PHY 321
Second Address Device 322
Controller 323
15
16
Network Router 20
Router Port 21
Interface 210
Primary Interface 211
Primary PHY 212
Backup Interface 213
Backup PHY 214
MUX 220
Address Device 230
Controller 240

FIGURE 3

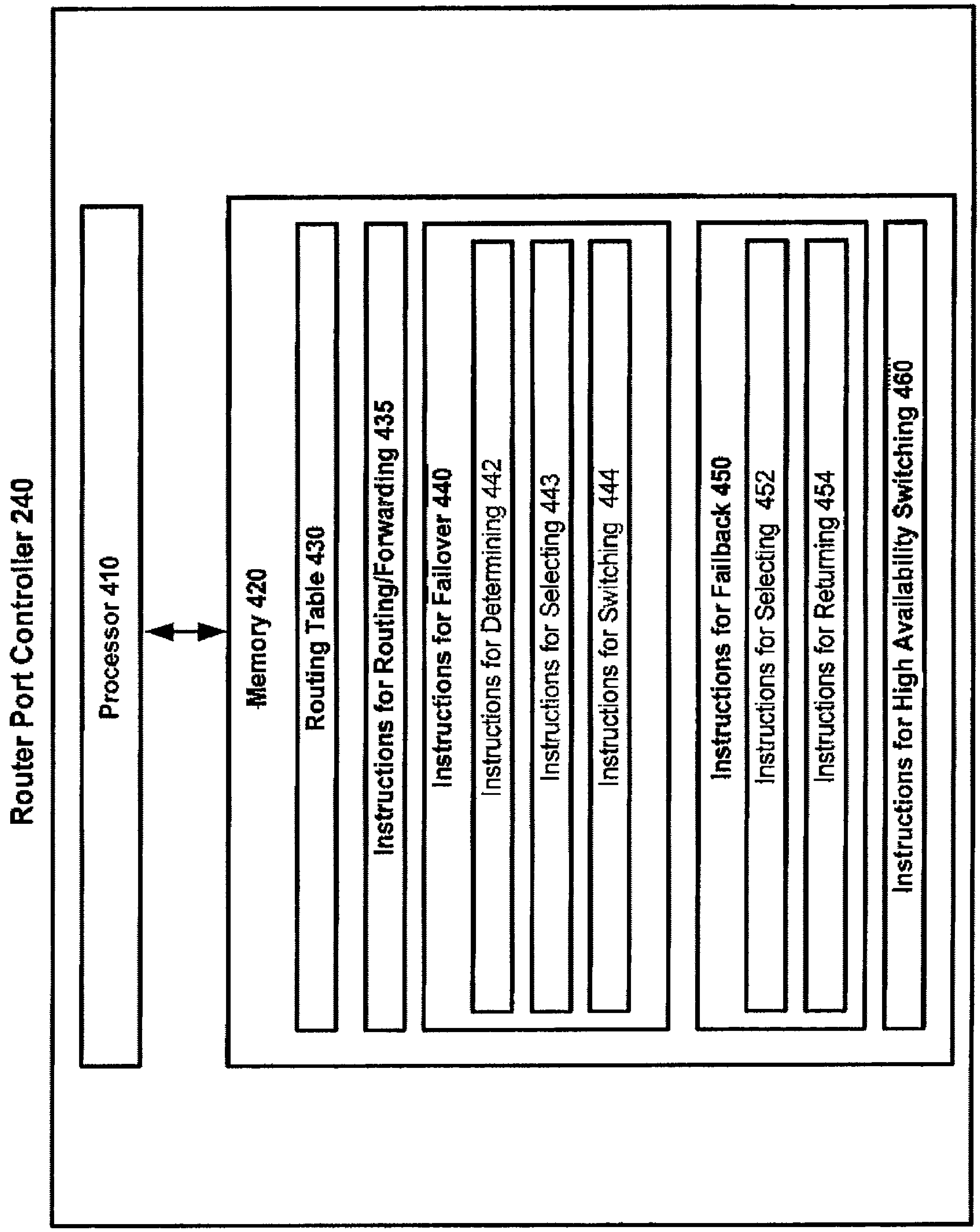
Router Port Controller 240
Processor 410
Memory 420
Routing Table 430
Instructions for Routing/Forwarding 435
Instructions for Failover 440
Instructions for Determining 442
Instructions for Selecting 443
Instructions for Switching 444
Instructions for Failback 450
Instructions for Selecting 452
Instructions for Returning 454
Instructions for High Availability Switching 460

FIGURE 4

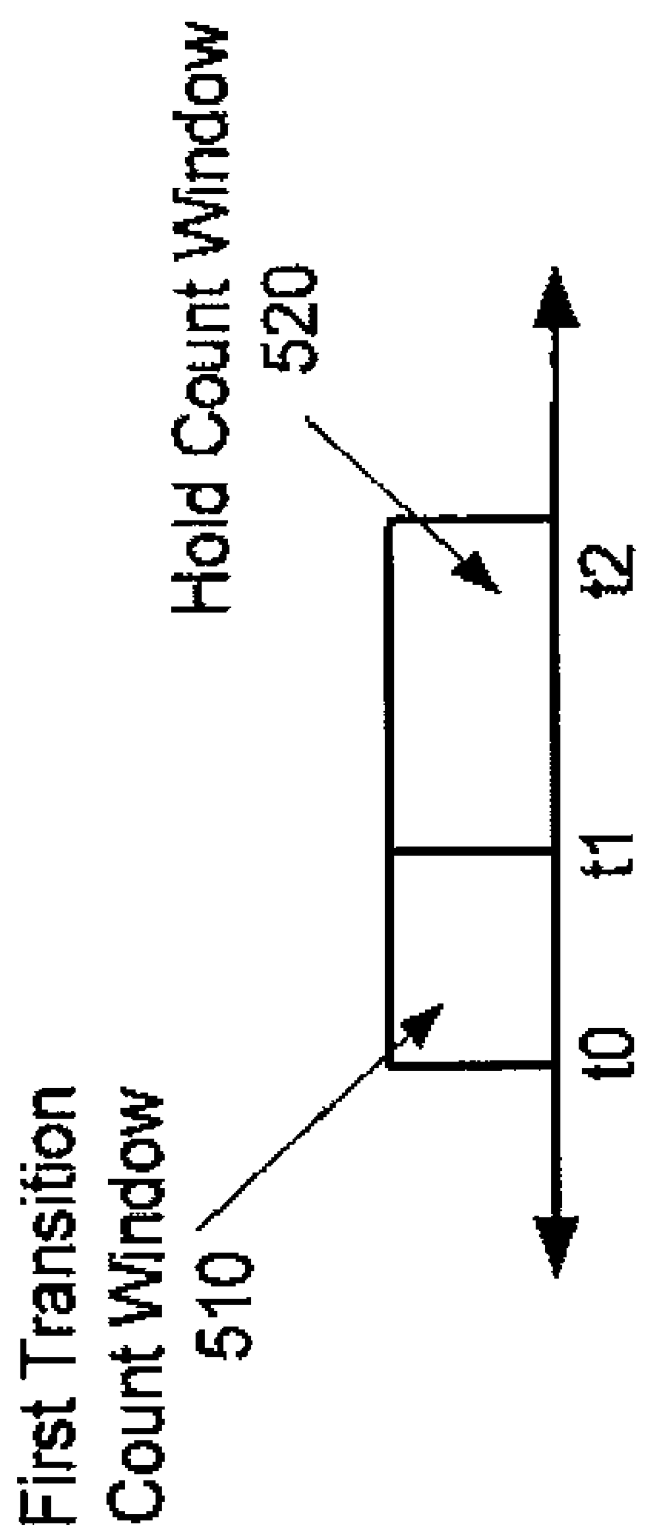

FIGURE 5A

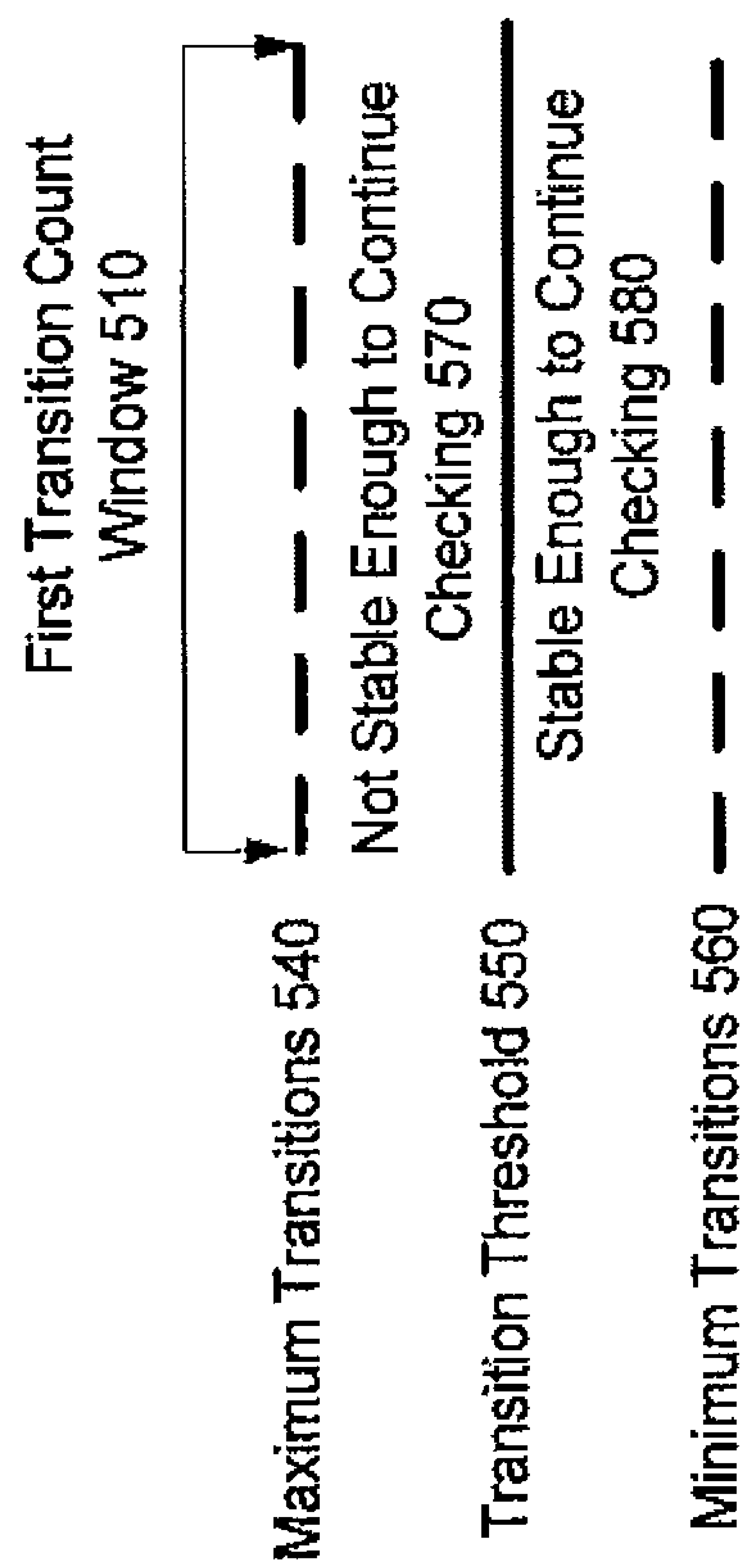

FIGURE 5B

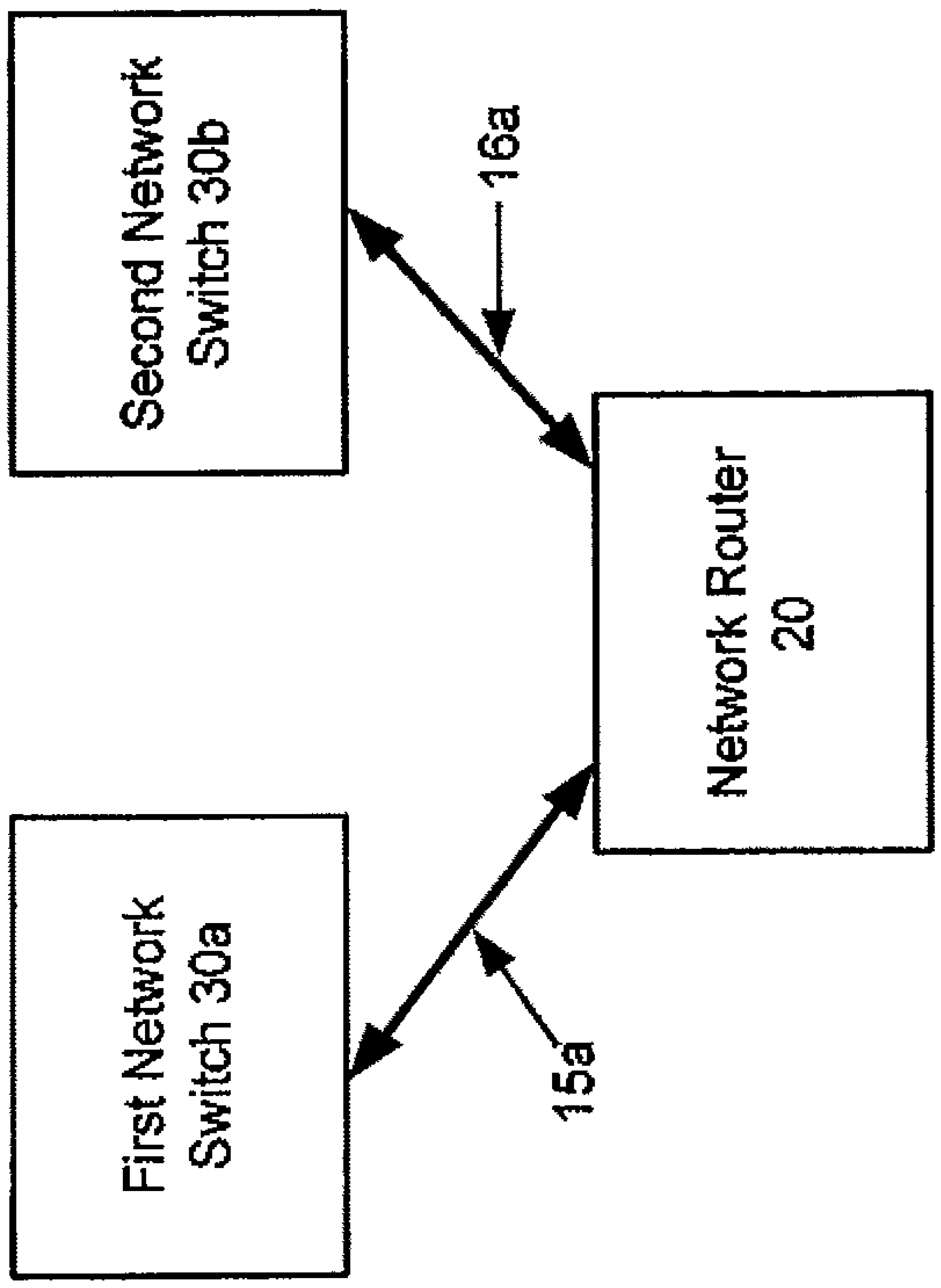

FIGURE 6B

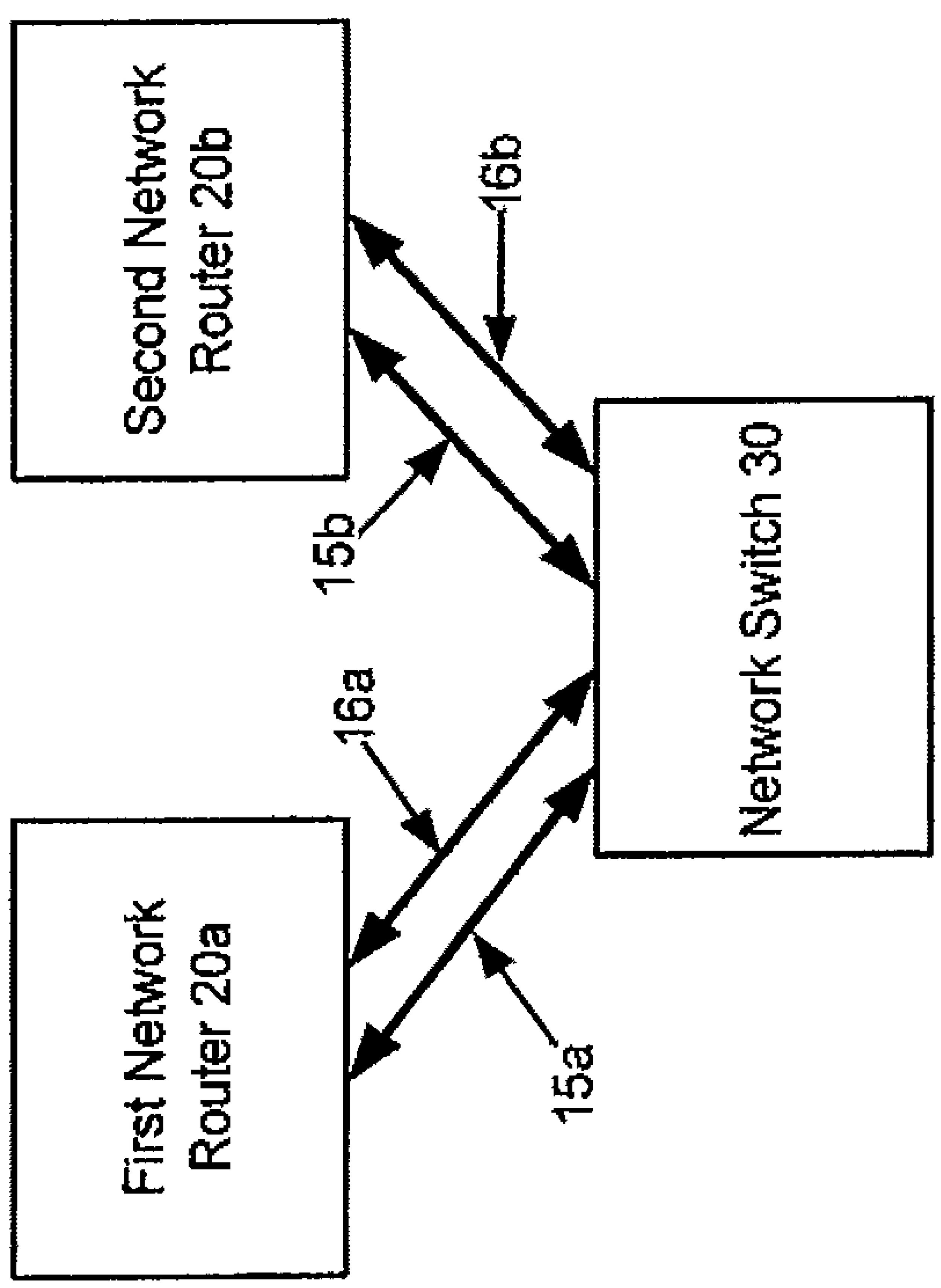

FIGURE 6A

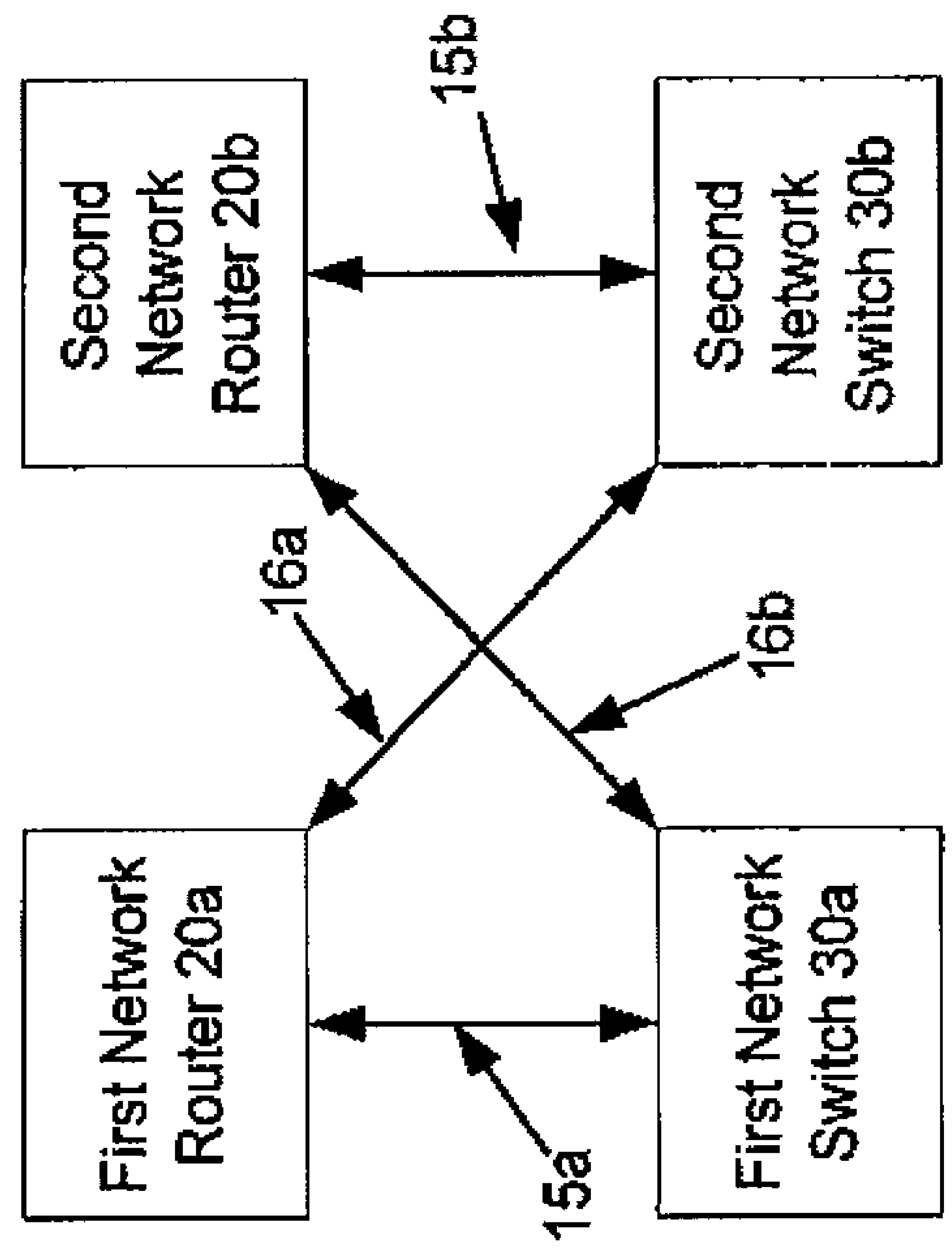

FIGURE 7B

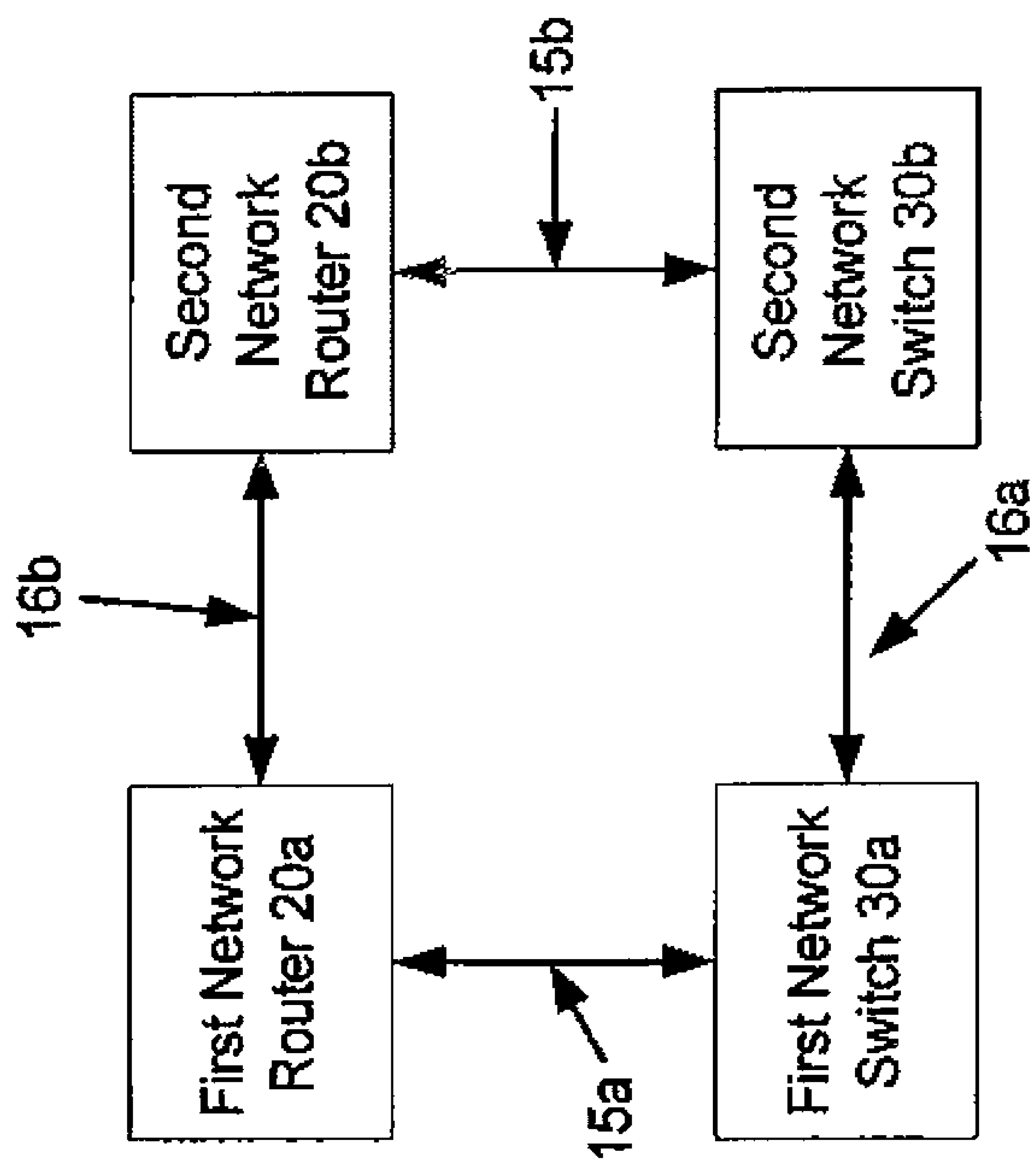

FIGURE 7A

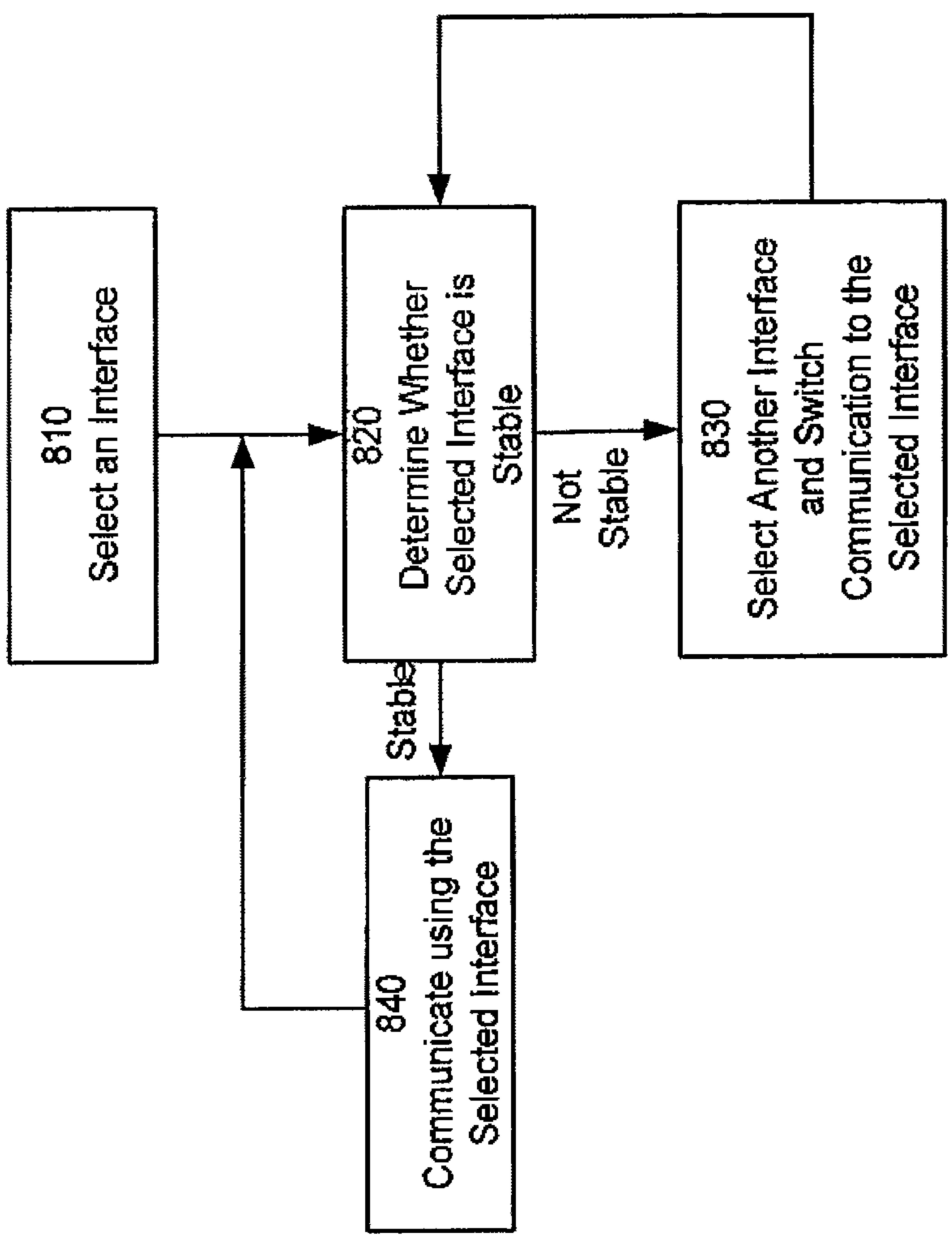
810
Select an Interface
820
Determine Whether
Selected Interface is
Stable
Not
Stable
830
Select Another Interface
and Switch
Communication to the
Selected Interface
Stable
840
Communicate using the
Selected Interface

FIGURE 8

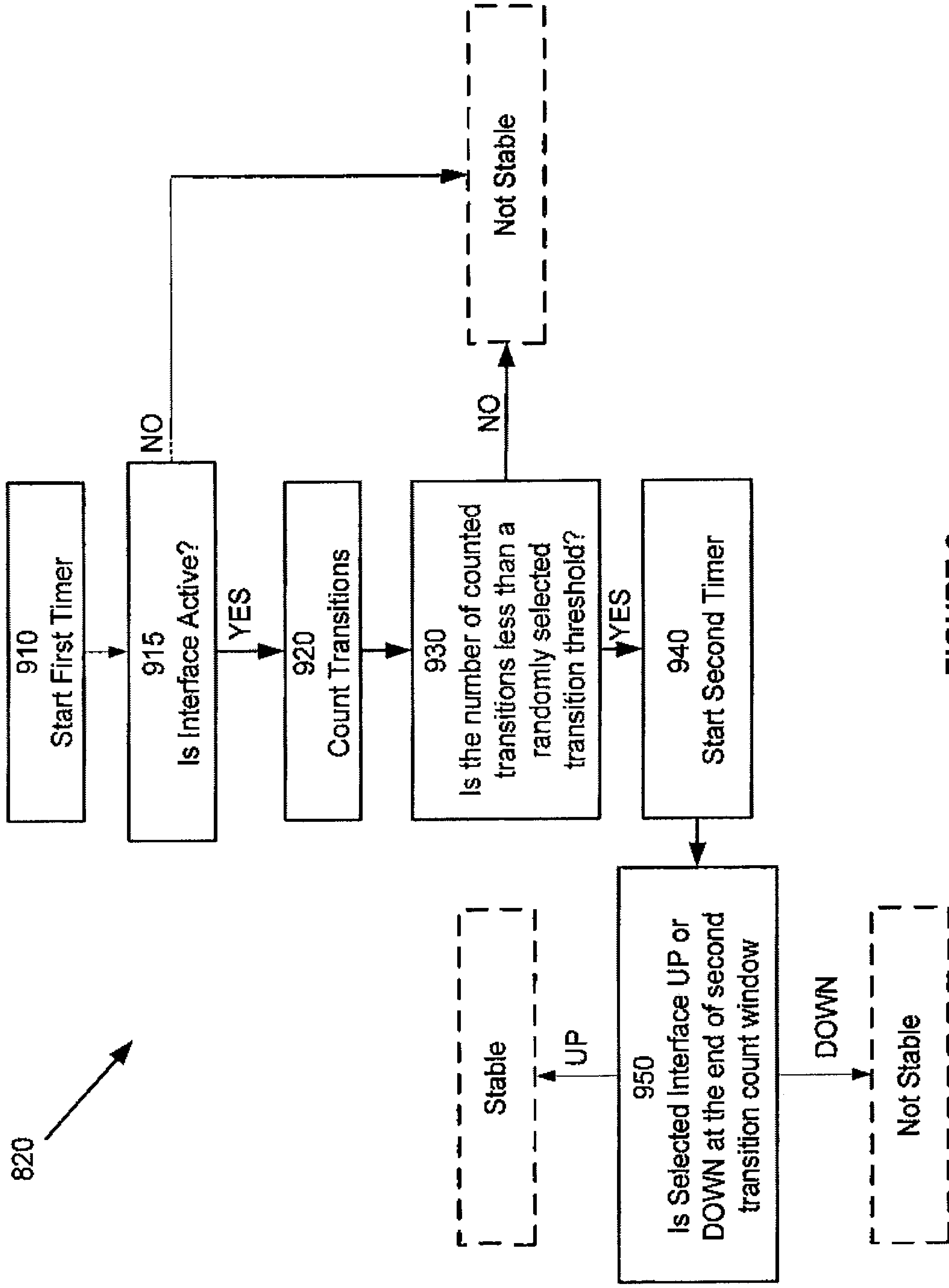
820
910
Start First Timer
915
Is Interface Active?
NO
YES
Not Stable
920
Count Transitions
930
Is the number of counted transitions less than a randomly selected transition threshold?
NO
YES
940
Start Second Timer
950
Is Selected Interface UP or DOWN at the end of second transition count window
UP
Stable
DOWN
Not Stable

FIGURE 9

FAILOVER AND FAILBACK OF COMMUNICATION BETWEEN A ROUTER AND A NETWORK SWITCH

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of U.S. patent application Ser. No. 12/329,115, filed Dec. 5, 2008, which is hereby incorporated by reference in its entirety.

FIELD OF TECHNOLOGY

The present embodiments relate to communication between a router and a network switch in a communication network. More specifically, the present embodiments may relate to failover and failback of communication between a router and a network switch.

BACKGROUND

Communication networks may include network switches. A network switch connects a communication device with a network router or other communication device. A transmission line, such as a copper cable or an optical fiber, may be used to transmit data between the network switch and the network router. The transmission line may be coupled with an interface of the network router. The interface may become inactive, for example, when the transmission line is disconnected from the network router or network switch. When the interface is inactive, the network switch is unable to communicate with the network router. Accordingly, the communication device, which uses the network switch to communicate with the network router, is unable to communicate with the network router or the other networks connected to the network router.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates one embodiment of a communication network;

FIG. **2** illustrates one embodiment of a network router coupled with a network switch;

FIG. **3** illustrates embodiments of a router port and switch ports;

FIG. **4** illustrates one embodiment of the router port controller;

FIG. **5**A illustrates one embodiment of the timing used to determine whether a selected interface is stable, and FIG. **5**B illustrates one embodiment of a randomly selected transition threshold.

FIGS. **6**A and **6**B illustrate embodiments of high availability communication;

FIGS. **7**A and **7**B illustrate embodiments of backup communication;

FIG. **8** illustrates one embodiment of a method for communication between a network switch and a network router; and

FIG. **9** illustrates one embodiment of a method for automatically determining whether a selected interface is stable.

DETAILED DESCRIPTION

The present embodiments relate to failover and failback of communication between a network router and a network switch. Failover includes moving the communication from a primary network to a backup network, so that the network router and network switch may communicate when a primary interface is inactive or flapping, for example, when the primary interface is not stable. Failback includes returning the communication back to the primary network from the backup network when the primary interface is active, for example, when the primary interface is stable. As used herein, communication includes the exchange of information, such as a message, data, or a signal. Flapping occurs when the energy status of the selected interface changes too often in a relatively short time.

In one aspect, a router includes a primary interface, a backup interface, a processor, and a memory. The primary interface is operable to communicate with a network switch over a primary network segment. The backup interface is operable to communicate with the network switch over a backup network segment. The primary interface and the backup interface may be coupled with the processor. The memory may be in communication with the processor. The memory may include computer code executable with the processor. The computer code may be configured to determine whether the primary interface is stable, the primary interface being stable when the primary interface may be used to exchange information with a network switch over the primary network. The computer code may be configured to activate the primary interface when the primary interface is determined to be stable. The primary interface may be activated for the exchange of information with the network switch over the backup network segment. The computer code may also be configured to activate the backup interface when the primary interface is determined to be not stable. The backup interface may be activated for the exchange of information with the network switch.

In a second aspect, a method is provided for selecting a first router interface for communication with a network switch. The selected first router interface is operable to communicate with the network switch using a first communication channel. The method may include determining whether the selected first router interface is stable, using the selected first router interface to communicate with the network switch when the selected first router interface is stable, and determining whether a second router interface is stable when the selected first router interface is not stable. Communication is moved to a second router interface when the second router interface is stable.

In a third aspect, a method includes selecting a first router interface for communication with a network switch. The selected first router interface is operable to communicate with the network switch using a first communication channel. A first number of transitions on the selected first router interface are counted. The number of transitions is counted during a first transition count window. A router determines whether the selected first router interface is stable based on the number of transitions. Communication with the network switch is moved to a second router interface when the selected first router interface is not stable. The second router interface is operable to communicate with the network switch using a second communication channel.

FIG. **1** illustrates a communication network **10**. The communication network **10** includes a network router **20**, a network switch **30**, and one or more communication devices **40**_a_, **40**_b_. The network switch **30** is coupled with or may be coupled with the one or more communication devices **40**_a_, **40**_b_ through network **13**. The network switch **30** is coupled with or may be coupled with the network router **20** through network **14**. The network router **20** may be coupled with other communication devices, such as routers, switches, and servers, through network **17**. The phrase "coupled with" includes directly connected to or indirectly connected through one or more intermediate components. Such intermediate components may include hardware and/or software based components. In alternative embodiments, the communication network **10** includes additional, fewer, or different components.

The communication network **10** is a local area network (LAN), personal area network (PAN), wide area network (WAN), global area network (GAN), Campus Area Network (CAN), intranet network, extranet network, or other system used for communication. For example, the communication network **10** is a system for ensuring that messages are transmitted between the router **20** and the network switch **30**. Within the router **20**, communication may be automatically or manually moved from a primary interface to a backup interface, for example, when the primary interface is not stable. The communication may be automatically or manually moved back to the primary interface when the primary interface is stable. In another example, the communication network **10** may automatically select the primary interface or the backup interface and move communication to the selected interface based on which interface is stable and/or preferred.

In one illustration, which will be referred to as "the illustration above," a business may use a communication network **10** according to the present embodiments. The business may employ a bookkeeper, Bill, and a marketer, Mary. Bill uses a laptop computer, which is connected to a network switch **30**. Mary uses a desktop computer, which is also connected to the network switch **30**. A communication channel couples the network switch **30** with a network router **20**, which is connected to the Internet. The communication channel may include a primary transmission line and a backup transmission line. The primary transmission line may be connected to a primary interface of the network router **20**, and the backup transmission line may be connected to a backup interface of the network router **20**. When the primary interface is not stable (e.g., when the primary network is disconnected from the primary interface), the network router **20** may move communication to the backup interface, such that the backup transmission line is used for communication with the network switch **30**. The network router **20** may move communication back to the primary transmission line when the primary interface is stable. Accordingly, even when the primary interface is not stable, Bill and Mary may communicate with the network router **20**, for example, accessing information on the Internet.

The networks **13**, **14** may be transmission lines, network segments, communication channels, communication networks, or communication cablings. As shown in FIG. **2**, the network **14** may include a primary channel **15** and a backup channel **16**. The primary channel **15** and backup channel **16** may be copper cables, optical fibers, other communication cablings, or any combination thereof. For example, if the primary channel **15** is a copper cable, then the backup channel **16** may be an optical fiber. In another example, if the primary channel **15** is a fiber optic, then the backup channel **16** may be a copper cable. In another example, if the primary channel **15** is a copper cable, then the backup channel **16** may be a copper cable as well. In the illustration above, the primary transmission line is the primary channel **15** and the backup transmission line is the backup channel **16**. The primary transmission line in the illustration above may be a copper cable and the backup transmission line may be an optical fiber.

The primary channel **15** and backup channel **16** may include connectors that connect the primary channel **15** and backup channel to the network router **20** and network switch **30**. For example, in the illustration above, the primary transmission line (e.g., a copper cable) may include a RJ45 Ethernet connector at one or both ends, and the backup transmission line (e.g., an optical fiber) may include a connector at one or both ends of the optical fiber that may be plugged into a small form-factor pluggable (SFP) module.

The network **17** may be a service provider (SP) network, Internet Protocol (IP) network, Internet SP network, Voice over Internet Protocol (VoIP) network, or other network for communication. For example, in the illustration above, the network **17** is an IP network that connects to the Internet. In another example, the network **17** may be used to communicate with another communication network **10**.

As shown in FIG. **2**, the network router **20** may include a router port **21** that is operable for communication with the network switch **30**. Additional, different, or fewer components may be provided. For example, the network router **20** may include one or more additional ports **33** for communicating with other devices, such as other network switches, servers, or communication devices connected to the network **17**. The one or more additional ports **33** may be communicatively coupled with the router port **21**.

The network router **20** may be a router, computer, server, open system interconnection (OSI) layer 3 switch, or other device for routing and forwarding messages. For example, the network router **20** may be a Cisco 76xx Router or Cisco 8xx Router that is operable to route messages between the network switch **30** and the network **17**. In another example, the network router **20** is operable to automatically determine when a primary interface and/or a backup interface is stable or not stable. The network router **20** may automatically move the communication from a non-stable interface to a stable interface. Alternatively, or additionally, the communication may be moved from the backup interface to the primary interface when the primary interface is stable and/or when the backup interface is not stable. One benefit of moving communication back and forth between the primary interface and backup interface is that the network router **20** may provide automatic Ethernet failover and failback to the communication devices **40***a*, **40***b*.

As used herein, a stable interface may be an interface that is active and not flapping. A non-stable interface is an interface that is inactive or flapping.

As shown in FIG. **3**, the router port **21** includes a port interface **210**, a multiplexor **220**, an address device **230**, and a controller **240**. Additional, different, or fewer components may be provided.

The port interface **210** may include a primary interface **211**, a primary PHY **212**, a backup interface **213**, and a backup PHY **214**. The primary interface **211** and backup interface **213** may be interfaces that connect or are operable to connect to the primary channel **15** and backup channel **16**. The primary interface **211** and backup interface **213** may be links for receiving connectors. For example, the primary interface **211** may include an RJ45 module for receiving a RJ45 connector, and the backup interface **213** may include a small form-factor pluggable (SFP) module. The primary interface **211** may communicate with the primary channel **15**, and the backup interface **213** may communicate with the backup channel **16**. The primary PHY **212** and the backup PHY **214** are physical mediums. The primary PHY **212** couples the primary interface **211** with the multiplexor **220**. The backup PHY **214** couples the backup interface **213** with the multiplexor **220**.

The primary PHY **212** and the backup PHY **214** are used to couple a link layer device, such as the address device **230**, with a physical medium, such as the primary channel **15** and the backup channel **16**. The primary PHY **212** and the backup PHY **214** may include a Physical Coding Sublayer (PCS) and a Physical Medium Dependent (PMD) layer. The PCS encodes and decodes the data that is transmitted and received. The purpose of the encoding is to make it easier for the receiver to recover the signal.

The multiplexor **220** may be operable to perform multiplexing and/or demultiplexing. The multiplexor **220** may combine the communication from the primary PHY **212** and the backup PHY **214** into one or more signals for communication to the address device **230** or router port controller **240**. The multiplexor **220** may be used to route information received at the primary interface **211** and/or backup interface **213** to the controller **240**. One benefit of using the multiplexor **220** may be that only a single address device **230** and a single router port controller **240** are necessary for the router port **21**. Although the router port **21** may communicate using two channels (e.g., the primary channel **15** and the backup channel **16**), the router port **21** only needs a single physical address and a single router port controller **240**. In addition, switching communication from the primary interface **211** to the backup interface **213** (or, vice versa) may be more efficient and cost effective since only a single address device **230** and a single controller **240** are needed.

The address device **230** may be a media access control (MAC) device or other device that includes a physical address for the router port **21**. The physical address may be used to communicate with the network switch **30**. The physical address may be a unique identifier that indicates the physical location of the address device **230**. For example, the address device **230** may be a MAC device that provides a MAC address. The address device **230** may be disposed outside of the router port controller **240** (as shown in FIG. **3**), or integrated with (e.g., disposed in) the controller **240**. For example, the MAC address may be hard-coded in the controller **240**.

FIG. **4** shows a controller **240**. The controller **240** includes a processor **410** and a memory **420**. The controller **240** may include additional, different, or fewer components. For example, the processor **410** may be connected to a remote memory, and thus, the controller **240** may not include memory **420**. In another example, as discussed above, the controller **240** may include the address device **230**.

The processor **410** may be a general processor, digital signal processor, application specific integrated circuit, field programmable gate array, analog circuit, digital circuit, combinations thereof, or other now known or later developed processor. The processor **410** may be a single device or a combination of devices, such as associated with a network or distributed processing. Any of various processing strategies may be used, such as multi-processing, multi-tasking, parallel processing, remote processing, or the like. The processor **410** is responsive to instructions stored as part of software, hardware, integrated circuits, firmware, micro-code or the like.

The processor **410** is operable to communicate with the network switch **30**, the one or more communication devices **40***a*, **40***b*, and/or one or more communication devices connected to the network **17**. To communicate, the processor **410** may transmit and/or receive information, such as messages, signals, or other data.

The processor **410** is operable to route or forward information. When the processor **410** receives information, the processor **410** may examine the received information and determine a final destination for the received information. The final destination may be determined based on the examination and/or a routing table **430**, which may be stored in memory **420**. The processor **410** may transmit the received information to the final destination. Alternatively, or additionally, the processor **410** may perform translations of protocols between different networks.

The processor **410** may select a primary interface **211** and/or a backup interface **213** for communicating with the network switch **30**. The primary interface **211** may be a preferred interface, which is connected to a preferred network, such as the primary channel **15**. A preferred interface may be an interface that a customer or provider prefers. The preference may be predetermined and stored in memory or determined based on stability of the interfaces. Alternatively, or additionally, there may be no preference or preference may be randomly selected. The backup interface **213** may be an interface used for backing up the preferred interface.

The processor **410** is operable to determine whether the selected interface is stable. Determining whether the selected interface is stable includes determining whether the selected interface is active (or, has been active or will likely become active), counting the number of transitions of energy for the selected interface in a first transition count window, comparing the number of transitions to a random transition threshold, determining whether the selected interface is active or inactive at the end of a second transition count window, or any combination thereof.

As used herein, the number of transitions of energy relates to the number of times the energy state on the primary PHY **212** and/or backup PHY **214** changes from an active state to an inactive state. For example, if energy is not detected on the primary PHY **212**, then the energy state of primary PHY **212** is inactive. However, if energy is detected on the primary PHY **212**, then the energy state of primary PHY **212** is active.

As shown in FIGS. **5**A and **5**B, the processor **410** may randomly select a time duration of a first transition count window **510** and a transition threshold **550**. A transition threshold may be selected that is between the maximum number of transitions **540** within the first transitions count window **510** and the minimum number of transitions **560** within the first transition count window **510**. For example, if each transition takes 100 milliseconds and the time duration of the first transition count window **510** (e.g., from t**0** to t**1**) is a randomly selected time duration, such as 5 seconds, then the maximum possible transitions **540** would be fifty (50) transitions (e.g., (5*1000)/100) and the minimum possible transitions **560** would be ten (10) transitions. Picking the random number between ten (10) and fifty (50) provides forty (40) possible numbers. Accordingly, if the routers are connected back to back, as shown in FIG. **2**, the probability of picking the same time is very low and hence lowering the probability of picking the wrong media and ending up in an infinite loop. Accordingly, the transition threshold is a random number between 10 and 50 transitions, for example, 25 transitions.

The processor **410** may use a timer to determine the first transition count window **510**, as shown in FIG. **5**. The transition count window **510** may have a randomly selected or predefined time duration. For example, as shown in FIG. **5**, the time duration of the first transition count window may be from time t**0** to time t**1**. The time duration of the first transition count window may be a random time duration, such 3-9 seconds. However, the time duration of the first transition count window **510** may be greater or less than this exemplary range. At the end of the first transition count window **510**, the processor **410** may stop the timer and determine the number of transitions. The time duration of the first transition count window **510** may be fixed, such as sequentially counting for different non-overlapping windows, or may be a moving window, such as counting for the most recent transitions.

The processor **410** may count the number of transitions during the first count window **510** and compare the number of counted transitions to the transition threshold **550**. As shown in FIG. **5**B, if the number of counted transitions is greater than or equal to the transition threshold **550**, then the selected interface is determined to be not stable enough to continue checking the selected interface **570**. In other words, when the number of counted transitions is greater than or equal to the transition threshold **550**, the selected interface is flapping. Accordingly, the selected interface may not be stable enough to use for communication. However, if the number of counted transitions is less than the transition threshold **550**, then the selected interface is determined to be stable enough to continue checking **580** whether the selected interface is stable.

As shown in FIG. **5**A, the processor **410** may determine whether the primary interface **211** and/or backup interface **213** have an active state or an inactive state at the end of a hold count window **520** (e.g., from t**1** to t**2**). For example, the processor **410** may determine whether the primary interface **211** and/or backup interface **213** have an active state or an inactive state at time t**2**. The time duration of the hold count window **520** may be shorter, longer, or the same as the time duration of the first transition count window **510**.

The processor **410** is operable to determine when selected interface is active ("UP") or inactive ("DOWN"). For example, the selected interface has an active state (e.g., UP) when energy is detected on the corresponding PHY (e.g., PHY **212** or PHY **214**). The primary interface **211** and/or backup interface **213** are considered to have an inactive state (e.g., DOWN) when energy is not detected on the corresponding PHY (e.g., PHY **212** or PHY **214**).

As used herein, the selected interface may be determined to be stable when the number of counted transitions is less than the randomly selected transition threshold and the selected interface is active at the end of the hold count window **520**. The selected interface may be determined to be not stable when the selected interface is inactive before or during the first transition count window or the selected interface is inactive at the end of the hold count window. The selected interface is determined to be flapping when the number of counted transitions is greater than or equal to the randomly selected transition threshold **550**. Flapping may occur when an interface on the network router **20** or network switch **30** has a hardware failure that will cause the network router **20** to determine that the primary interface **211** and/or the backup interface **213** is alternately UP and DOWN. Flapping may be caused by pathological conditions (e.g., hardware errors, software errors, configuration errors, intermittent errors in communications links, or unreliable connections) within the network **10** which cause information to be repeatedly advertised and withdrawn.

The processor **410** is operable to move communication from a primary interface **211** to a backup interface **213** when the primary interface **211** is inactive or not stable. Moving the communication from a primary channel **15** to a backup channel **16** may be referred to as failover. Moving the communication may include transferring communication to a stable interface. In one example, as shown in FIG. **3**, when primary interface **211** is inactive or not stable, the processor **410** begins communication with the network switch **30** across the backup channel **16**. The processor **410** may transmit information to the second address device **322**, for example, through the second interface **320** and backup PHY **321**.

One benefit of moving the communication to a stable interface may be that the network router **20** and network switch **30** may still communicate when the primary interface **211** is inactive or flapping. This provides redundancy in the communication. For example, in the illustration above, when the primary transmission line between the network router and network switch is disconnected for maintenance, Mary may still have access to the Internet using the backup transmission line. The failover may be automatic such that the performance of maintenance does not require manual reconfiguration.

In one embodiment, the processor **410** may deteunine whether the backup interface **213** is stable before moving communication. Determining whether the backup interface **213** is stable may include determining whether the backup interface **213** is active and/or stable. One benefit of checking the backup interface **213** before moving the communication may be that the unnecessary movement of communication may be prevented. Additional backup interfaces may be provided, such that failover may be to any backup and a backup may failover to another backup.

The processor **410** is operable to perform failback. Failback includes returning the communication back to the primary channel **15** from the backup channel **16**. Returning the communication may include moving the communication or transferring the communication to a primary interface **211**. The communication may be returned to the primary channel **15**, for example, when the backup channel **16** is inactive or flapping, the primary channel **15** is stable, or as a rule.

The processor **410** is operable to select the primary interface **211** or the backup interface **213** for communication with the network switch **20**. For example, based on whether the primary interface **211** and/or backup interface **213** are active, inactive, stable, or not stable, the processor **410** may select an interface for communication. Selection may include reading a switching table to determine whether to use the primary interface **211** or the backup interface **213** for communication. The network router **20** may use a switching table, such as Table 1, to select the interface used for communication with the network switch. Table 1 is based on the primary interface being the preferred interface.

TABLE 1

Primary Interface	Backup Interface	Interface Selected
Stable	Stable	Primary Interface
Stable	Not Stable	Primary Interface
Not Stable	Stable	Backup Interface
Not Stable	Not Stable	Algorithm Picks the Interface

As shown in Table 1, the processor **410** may select the primary interface **211** when the primary interface **211** is active, for example, UP. The processor **410** may automatically select a stable interface when the primary interface **211** is down or flapping. Selecting a stable interface may include selecting the backup interface **213** or another interface that is active. For example, as shown in Table 1, when the primary interface **211** is inactive or not stable, but the backup interface **213** is stable, the processor **410** may move communication to the backup interface **213**. In another example, when the primary interface **211** and the backup interface **213** are inactive or not stable, the processor **410** may select an interface supported by another router.

Moving communication may include activating and deactivating the primary interface **211** and/or the backup interface **213**. For example, if the primary interface **211** is inactive or flapping, the processor **410** may deactivate the primary interface **211** and activate the backup interface **213**. In another example, when the primary interface **211** is active or becomes active, the processor **410** may deactivate the backup interface **213** and activate the primary interface **211**. Activating an interface may include configuring the controller **240** and/or multiplexor **220** such that the controller **240** communicates the activated interface. For example, if the primary interface **211** is activated, then the controller **240** communicates with the primary interface **211**. Deactivating an interface may include configuring the controller **240** and/or multiplexor **220** such that the controller **240** does not communicate with the deactivated interface.

The processor **410** is operable to perform high availability switching. High availability switching includes switching communication between two or more network routers **20** and/or network switches **30**. As shown in FIG. **6**A, two or more network routers **20** are configured so that when a first primary channel **15***a* and a first backup channel **16***a*, which are connected between a first router **20***a* and a network switch **30**, are not stable, a second router **20***b* assumes the workload of both the first network router **20***a* and the second network router **20***b*. For example, when the first primary channel **15***a* and the first backup channel **16***a* are not stable, the second primary channel **15***b* or the second backup channel **16***b* may be used for communication. The first network router **20***a* may instruct the second network router **20***b* to begin communication with the network switch **30**.

One benefit of high availability switching is that when the primary and backup interfaces **211**, **213** of a first network router **20***a* are not stable, the network switch **30** may still communicate with the second network router **20***b*, such that the communication devices **40***a*, **40***b* may still communicate with the second network router **20***b*. In the illustration above, even if the network router goes down, Mary may still access the Internet using a second network router **20***b*. In addition, the second network router **20***b* has two levels for communication, for example, the second primary channel **15***b* and the second backup channel **16***b*.

In one embodiment, when the first network router **20***a* resumes operation, the second network router **20***b* may perform a failback, which returns the communication to normal operation, for example, using the first primary channel **15***a* or first backup channel **16***a* between the first network router **20***a* and the network switch **30**.

FIG. **6**B shows an alternative embodiment of failover. As shown in FIG. **6**B, when a router interface connected to a first primary channel **15***a* is not stable, the network router **20** may switch communication to a router interface connected to a first backup channel **16***a*. The first primary channel **15***a* may be connected to a first network switch **30***a* and the first backup channel **16***a* may be connected to a second network switch **30***b*.

FIG. **7**A and FIG. **7**B show alternative embodiments of high availability switching. As shown in FIGS. **7**A and **7**B, when the router interface connected to the first primary channel **15***a* is inactive or not stable, the first network router **20***a* may switch communication to a router interface connected to the first backup channel **16***a*. When the router interfaces connected to a first primary channel **15***a* and a first backup channel **16***a* are inactive or not stable, the first network router **20** may switch communication to a second primary channel **15***b*. When the interfaces connected to the first primary channel **15***a*, the first backup channel **16***a*, and the second primary channel **15***b* are inactive or not stable, the second network router **20** may switch communication to a router interface connected to the second backup channel **16***b*.

The memory **420** may be computer readable storage media. The computer readable storage media may include various types of volatile and non-volatile storage media, including, but not limited to, random access memory, read-only memory, programmable read-only memory, electrically programmable read-only memory, electrically erasable read-only memory, flash memory, magnetic tape or disk, optical media and the like. The memory **420** may be a single device or a combination of devices. The memory **420** may be adjacent to, part of, networked with and/or remote from the processor **410**.

As shown in FIG. **4**, the memory **420** may store a routing table **430**. The routing table may include the routes (and in some cases, metrics associated with those routes) to particular network destinations. The routing table may include a topology of one or more networks. The memory **420** may store other lists, databases, or tables. For example, the memory **420** may store a forwarding table. The processor **410** may use a forwarding table to find a proper interface to which the input interface should send information.

The memory **420** may be a computer readable storage media having stored therein data representing instructions executable by the programmed processor **410**. The memory **420** stores instructions for the processor **410**. The processor **410** is programmed with and executes the instructions. The functions, acts, methods or tasks illustrated in the figures or described herein are performed by the programmed processor **410** executing the instructions stored in the memory **420**. The functions, acts, methods or tasks are independent of the particular type of instructions set, storage media, processor or processing strategy and may be performed by software, hardware, integrated circuits, firmware, micro-code and the like, operating alone or in combination. The instructions are for implementing the processes, techniques, methods, or acts described herein.

As shown in FIG. **4**, the memory **420** may include instructions for routing/forwarding **435**, instructions for failover **440**, instructions for failback **450**, and instructions for high availability switching **460**. Additional, different, or fewer instructions may be provided.

The instructions for routing/forwarding **435** may be executed to route or forward information. For example, the instructions **435** may be executed to receive information from a communication device or a network switch, analyze the received information to determine a destination address, and route or forward the received information to the destination address. Analyzing the received information may include using a routing table to determine the destination address.

The instructions for failover **440** may be executed to switch communication from a primary interface to a backup interface, so that the network router and network switch may communicate when a primary interface is inactive or not stable. Switching communication may include moving communication from a first communication channel to a second communication channel. As shown in FIG. **4**, the instructions for failover **440** may include instructions for determining **442**, instructions for selecting **443**, and instructions for moving communication to the selected interface **444**. The instructions for determining **442** may be executed to determine whether an interface is stable, for example, by determining whether the interface is active, inactive, and/or flapping. The instructions for selecting **443** may be executed to select an interface for communication. The instructions **443** may be executed to select a preferred channel, a stable interface, an active interface, or a combination thereof. The instructions for switching **44** may be executed to move communication to the selected interface.

The instructions for failback **450** may be executed to return communication back to a primary channel from a backup channel. Returning the communication back to the primary channel may include moving communication to a primary interface. As shown in FIG. **4**, the instructions for failback **450** may include instructions for selecting **452** and instructions for returning **454**. The instructions for selecting **452** may be executed to select an active and/or stable interface.

The instructions for high availability switching **460** may be executed to move communication to a second network router or a second network switch. Moving communication may include transferring communication from a first network router or first network switch to a second network router or second network switch that has a stable interface.

As shown in FIG. **3**, the network switch **30** may include a first switch port **31** and a second switch port **32**. The network switch **30** may include additional, different, or fewer components. For example, the network switch **30** may include one or more ports that connect to the one or more communication devices **40**. In another example, the network switch **30** may include additional ports that connect to the network router **20**, for example, a third switch port may be provided. The third switch port may be connected to a backup network that may backup the first and second networks **15**, **16**. For example, if the interfaces connected to the first and second networks **15**, **16** are inactive or not stable, then the backup network may be used for communication between the network router **20** and the network switch **30**. In another example, as shown in FIG. **2**, the network switch **30** may include one or more communication ports **33** that may be used to couple the communication devices **40** with the first switch port **31** and second switch port **32**. In another example, the network switch **30** may include a buffer, which can hold data packets to be forwarded.

The network switch **30** is operable to allow different nodes, such as the one or more communication devices **40***a*, **40***b*, of the communication network **10** to communicate directly with one another in a smooth and efficient manner. The network switch **30** may work at Layers 1 (Physical) and 2 (Data Link) of the OSI Reference Model. The network switch **30** may analyze incoming data (e.g., voice data and/or text data) to determine a destination address for the incoming data. Based on that address, a transmission path is set up through a switching matrix between the incoming and outgoing physical communications ports and links.

As shown in FIG. **3**, the first switch port **31** and second switch port **32** include first and second interfaces **310**, **320**; first and second PHYs **311**, **321**; first and second address devices **312**, **322**; and first and second controllers **313**, **323**. The first switch port **31** and second switch port **32** may include additional, different, or fewer components.

The first interface **310** and second interface **320** may be mechanical and/or electrical links that couple the primary and backup channels **15**, **16** with the first and second PHYs **311**, **321**. For example, as shown in FIG. **3**, the first interface **310** may couple the primary channel **15** with the first PHY **311**, and the second interface **310** may couple the backup channel **16** with the second PHY **321**.

The first address device **312** and second address device **322** may be media access control (MAC) devices or other devices that include a physical address for the first switch port **31** and second switch port **32**. The physical address may be used to communicate with the network router **20**. The physical address may be a unique identifier that indicates the physical location of the first address device **312** and the second address device **322**. For example, the first address device **312** may be a MAC device that provides a MAC address. The first address device **312** may be disposed outside of the controller **313** (as shown in FIG. **3**), or integrated with (e.g., disposed in) the controller **313**. For example, the MAC address may be hard-coded in the controller **313**.

The controllers **313**, **323** may include processors and memories. The controllers **313**, **323** may switch data received from one or more communication devices **40**. For example, the controller **313** may receive incoming data from a first communication device, analyze the incoming data to determine a destination address (e.g., associated with a communication device **40***a*, **40***b*, the network router **20**, or a communication device connected to the network switch **30**), and transmit the incoming data to the network router **20**.

The one or more communication devices **40** may be personal computers, servers, routers, network nodes, hubs, remote terminals, network switches, or other devices placed in a network. For example, in the illustration above, the laptop is a communication device **40** and the personal computer is a communication device **40**. The one or more communication devices **40** may be operated by a user, for example, to browse the Internet or transmit messages to other communication devices.

FIG. **8** is a flowchart illustrating one embodiment of communication between a network router and a network switch. The method may include selecting a first network interface for communication, determining whether the selected network interface is stable, using the selected network interface for communication between the network router and the network switch. The method may also include, for example, selecting another interface and switching the communication to the other network interface when the selected network interface is inactive or not stable.

At block **810**, a network router selects a first interface. The first interface may be a preferred interface, for example, connected to a preferred network, such as a copper cable or an optical fiber. The network router may select the first interface using a polling process or reading a preferred interface from memory. The polling process may be used to check the status of the interface.

In block **820**, the network router determines whether the selected interface is stable. The network router may use a stability method, such as the method shown in FIG. **9**, for determining whether the selected interface is stable. At block **910**, as shown in FIG. **9**, a first timer is started once communication is switched to the selected interface.

In one embodiment, the router may determine whether the selected interface is, was, or will likely be active, as shown in block **915**. In other words, the router may determine if there is, was, or will likely have energy on the corresponding PHY. If the corresponding PHY does not have energy, then the selected interface may be inactive and the router may select another interface and switch communication to that interface, as shown in block **830** of FIG. **8**. In an alternative embodiment, the router may determine if the selected interface is active prior to starting the first timer. In other words, the acts represented in block **915** may be performed prior to the acts represented in block **910**.

At block **920**, the router counts a number of transitions, for example, from UP to DOWN and/or DOWN to UP on the selected interface during a first transition count window. The selected interface is UP when energy is detected on the selected interface, for example, on the PHY corresponding to the selected interface. The selected interface is DOWN when energy is not detected on the selected interface, for example, on the PHY corresponding to the selected interface. At the end of the first transition count window, the router may stop the timer and determine the number of transitions.

As shown in block **930**, the router may compare the number of counted transitions, which were counted during the first transition count window, to a randomly selected transition threshold. The randomly selected transition threshold may be less than the maximum number of transitions for the first transition count window and greater than the minimum number of transitions for the first transition count window. For example, when the number of counted transitions is below the randomly selected transition threshold, the selected network may be determined to be stable enough to continue to finish checking whether the selected interface is stable. However, when the number of transitions is greater than or equal to the randomly selected transition threshold, the selected interface may be determined to be not stable. Accordingly, the router may select another interface and switch communication to the selected interface, as shown in block **830**. In an alternative embodiment, the randomly selected transition threshold may be a predefined or preselected transition threshold.

At block **940**, when the number of counted transitions is below the randomly selected transition threshold, a second timer is started. The second timer is used to define a hold count window. The time duration of the hold count window **520** may be longer than the time duration of the first transition count window. As shown at block **950**, the router may determine whether the selected interface is inactive (e.g., UP) or active (e.g., DOWN) at the end of the hold count window. For example, if the selected network is inactive at the end of the hold count window, then the selected interface is determined to be not stable and communication is switched to another network, as shown in block **830** of FIG. **8**. However, if the selected network is active at the end of the hold count window, then the selected interface is determined to be stable and used to communicate with the network switch, as shown in block **840** of FIG. **8**. The selected interface may be continuously or periodically checked to determine whether the selected interface is stable.

In one alternative embodiment, if the selected interface is not the preferred interface, the network router may periodically poll the preferred interface. The polling may take place before, during, or after the network router determines whether the selected interface is stable. If the preferred interface is UP, the network router may switch communication to the preferred interface. Communication may be switched back to the preferred interface, even when the backup interface is UP. One benefit of automatically reverting back to the preferred interface may be that the preferred interface and preferred network may be used as much as possible. In addition, the network administrator may not be required manually switch the communication back to the preferred network.

While the invention has been described above by reference to various embodiments, it should be understood that many changes and modifications can be made without departing from the scope of the invention. It is therefore intended that the foregoing detailed description be regarded as illustrative rather than limiting, and that it be understood that it is the following claims, including all equivalents, that are intended to define the spirit and scope of this invention.

We claim:

1. A network switch comprising:

a first interface in communication with a primary network segment and a first physical layer;

a second interface in communication with a secondary network segment and a second physical layer;

at least one controller configured to analyze data received at the first interface, when the first physical layer is stable according to a number of energy state changes of the first physical layer during a first time duration and the first interface being active at an end of a hold count window of a second time duration, and the at least one controller further configured to analyze data received at the second interface, when the first physical layer is unstable.

2. The network switch of claim **1**, wherein whether the first physical layer is stable is based on the number of energy state changes of the first physical layer during the first time duration compared to a randomly selected transition threshold.

3. The network switch of claim **2**, wherein the first time duration comprises a randomly selected time duration.

4. The network switch of claim **1**, wherein the primary network segment comprises a copper cable and the secondary network segment comprises an optical fiber.

5. The network switch of claim **1**, wherein the at least one controller is configured to analyze the data received at the second interface when the second interface is stable.

6. A method comprising:

selecting a first interface of a port for communication using a first network segment;

counting a number of energy state transitions at the first interface during a predetermined transition count window to determine a stability of the first interface, wherein the predetermined transition count window comprises a randomly selected time duration;

communicating via the first interface of the port and the first network segment, when the first interface is stable;

counting a number of energy state transitions at a second interface to determine a stability of the second interface of the port, when the first interface is unstable; and

moving communication to the second interface of the port and a second network segment, when the second interface is stable and the first interface is unstable.

7. The method of claim **6**, further comprising:

comparing the number of energy state transitions at the first interface to a randomly selected transition threshold.

8. The method of claim **7**, further comprising determining that the first interface is stable when the number of energy state transitions at the first interface is less than the randomly selected transition threshold.

9. The method of claim **6**, further comprising:

monitoring the first interface to determine whether the first interface is stable; and

moving communication via the port back to the first interface and the first network segment, when the first interface is stable.

10. The method of claim **6**, further comprising switching communication to another network device, when the first interface and the second interface are unstable.

11. The method of claim **6**, wherein the first interface is coupled with a copper cable and the second interface is coupled with an optical fiber.

12. The method of claim **6**, wherein the first network segment includes copper and the second network segment includes optics.

13. The method of claim **6**, wherein determining the stability of the first interface further comprises determining whether the first interface is active at an end of a hold count window.

14. A method, comprising:

selecting a first interface of a network device in communication with a primary network segment;

determining stability of the first interface based on a number of energy state changes of the first interface during a first time duration being below a threshold, and the first interface being active at an end of a hold count window of a second time duration;

analyzing data received at the first interface when the first interface is stable;

selecting a second interface of the network device in communication with a secondary network segment, when the first interface is unstable; and analyzing data received at the second interface when a number of energy state changes of the second interface is below the threshold.

15. The method of claim **14**, wherein the first time duration is randomly selected.

16. The method of claim **14**, wherein the threshold is a randomly selected threshold.

17. The method of claim **14**, wherein the primary network segment includes a copper cable and the secondary network segment includes an optical fiber.

18. The method of claim **14**, wherein the primary network segment includes optics and the secondary network segment includes a metal conductor.

19. The method of claim **13**, wherein, a duration of the hold count window is longer than a duration of the predetermined transition count window.

20. The method of claim **14**, wherein the second time duration is randomly selected.

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